Design projects at INL's Center for Space Nuclear Research took summer fellows to the depths of the ocean and the surface of the moon.

Space Nuclear Research fellows unveil ambitious summer projects

by Roberta Kwok, *Research Communications Fellow*

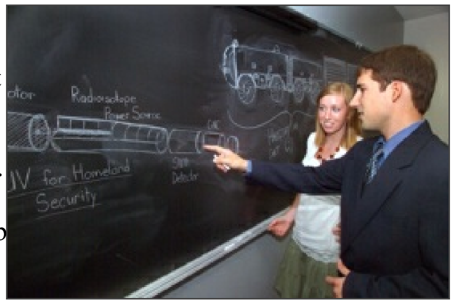
Underwater bomb detectors, lunar trains and terrorist-resistant fuel capsules all made appearances at the final presentations by Idaho National Laboratory's Center for Space Nuclear Research Summer Fellows, a group of students gathered from around the country to tackle tough engineering problems over their summer break. The students, selected from a nationwide search, dreamed up solutions to scenarios ranging from nuclear threats at U.S. ports to mobile expeditions on the moon.

The summer program "exceeded my expectations," says Josh Valentine, a master's degree student in mechanical engineering from the University of Cincinnati who presented his work July 28 at INL's Engineering Research Office Building with the other Fellows. "I travelled a long way to come out here, and it was worth it."

Valentine was one of 14 students chosen to participate in this year's program, which drew from 10 states and the United Kingdom. Working in teams, the Fellows designed solutions to tricky problems posed by INL's space nuclear center (operated by the Universities Space Research Association), NASA and the Department of Homeland Security. Some students roamed into futuristic territory with computer simulations of smart underwater vehicles and mobile lunar bases, while others grappled with the challenges of building tougher nuclear fuel capsules or planning an irradiation experiment for NASA.

The students' work over their 10-week stay has been "tremendous," says CSNR Director Steven Howe, who supervised the research. "The projects give us a base technology capability that's pretty much unique in the country."

An underwater sentinel



Summer fellows Tess Howell and Jeff Katalenich sketch plans for an unmanned underwater vehicle that can detect nuclear bombs on ships arriving at U.S. ports.

One team had an ambitious mission: design an unmanned underwater vehicle (UUV) that can detect nuclear bombs on moving ships.

The project, funded by the Department of Homeland Security, aims to fill a key security gap at U.S. ports. Currently, officials scan only about 2 percent of incoming cargo ships for suspicious nuclear materials. These scans take place when the ship is already in port, leaving the possibility that a bomb hidden in a cargo container could detonate before officials can react.

"It leaves a hole for terrorists," says team leader Jeff Katalenich, an undergraduate in mechanical engineering at Michigan Technological University in Houghton.

An unmanned underwater vehicle could solve these problems by patrolling the waters well outside port, maneuvering under the ships to detect potential nuclear threats. But existing UUVs aren't fast enough to keep up with moving ships without frequent refueling. To allow long-duration missions, the team explored the possibility of swapping various radioisotope power sources into a battery-powered model, eventually settling on curium as a promising candidate.

Scanning for nuclear materials proved more difficult because the water and ship's hull block too much radiation to allow a detectable signal. An underwater bomb detector would need to use more active methods to sniff out suspicious cargo, the team concluded, such as beaming particles into the ship to activate neutron bursts from the hidden material.

The eventual goal is to design a UUV that can last for five years without resurfacing, Katalenich says. Such a vehicle could have other applications as well, like mapping the ocean floor or assisting deep offshore oil drilling.

A safe radioisotope shell

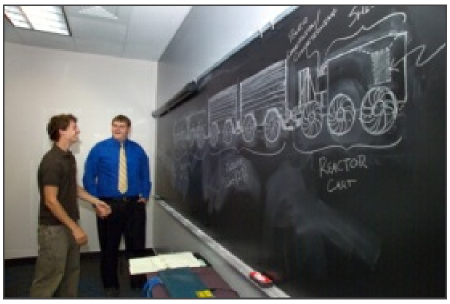
If a radioisotope-powered UUV is prowling the oceans, engineers need to make sure it doesn't become a dangerous weapon in unfriendly hands. Luckily, another team led by Rob O'Brien, who is pursuing a doctorate in space instrumentation at the University of Leicester in the United

Kingdom, has the answer.

O’Brien’s team spent the summer becoming experts on a tough material: tungsten. Using a new instrument at INL called the Spark Plasma Sintering Furnace – one of only six in the U.S. – they fabricated tungsten capsules at much lower temperatures than would be needed with traditional methods. These capsules could provide a nearly impenetrable shell for radioisotopes, preventing terrorists from extracting the radioactive material to make a dirty bomb.

The shells could also prove useful for nuclear thermal rockets (NTR), a potential transport method to launch astronauts to Mars. Previous nuclear rocket designs using graphite fuel rods have stalled because the radioactive material escapes into the exhaust stream, but tungsten is less prone to erosion and could protect the fuel in the event of a launch accident.

“The biggest flaw with historical NTR technology has been the release of radioactive materials into the exhaust stream,” O’Brien says. “If we address that issue, there’s absolutely no reason why systems can’t be developed in the very near future.”



The mobile lunar base team, which included Logan Sailer and team leader Aaron Craft, envisioned a trainlike set of cars with a nuclear reactor in the caboose.

Going mobile

Another team had its sights set on the moon. The team envisioned a trainlike mobile base powered by a nuclear reactor that could ferry astronauts around the lunar surface, allowing them to conduct experiments at different sites.

Other U.S. Department of Energy laboratories are already working with NASA to develop a stationary nuclear-powered lunar base that keeps the reactor at a safe distance from the astronauts. To go mobile, the students had to design a base within launch weight limits that would shield astronauts from the nuclear reactor that was essentially riding in the caboose.

The team came up with a design that provided thick shielding around the front of the reactor, which faces the astronauts’ habitation car, and thinner shielding around the back. To reduce initial launch mass, the team suggested, a “smart shield” design could leave the back panels empty and only later pump in borated water – which absorbs neutrons – when astronauts want to explore the area beyond the base.

Another challenge presented by NASA’s stationary base model was the radiator, a large Mylar sail that released excess heat but might break on a bumpy ride. The students proposed, among other solutions, that the base run at only half-power while moving – using a smaller, more durable radiator – then extend a second radiator when stopped to allow the base to fire up to full power.


Research Fellow Anthony Hardy helped investigate possible facilities where NASA could test the effects of irradiation on samarium-cobalt magnets, a key component of a reactor-driven engine.

In a complementary effort, a fourth team designed an experiment for NASA to ensure that magnets used to power a reactor-driven engine wouldn’t deteriorate under constant irradiation. The team investigated testing capabilities and costs at five facilities, including the Advanced Test Reactor at INL. The experiment’s results could also apply to the UUV, which might use the same magnet-dependent engine.

Saving the world

After exploring the depths of the ocean and the surface of the moon, where will CSNR Fellows go next? Howe says that next summer, students might redesign the UUV for reconnaissance on Europa, one of Jupiter’s moons, where it could use its radioisotope power to melt through the ice. Another project might involve designing a nuclear rocket that could intercept a deadly asteroid bound for the Earth.

“If we have a nuclear rocket, we can reach the asteroid fast enough to deflect it,” Howe says. “So that might be a nice project for students to work on: to save the planet.”

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